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SECOND-ORDER SCHEDULES OF TOKEN REINFORCEMENT: COMPARISONS OF PERFORMANCE UNDER FIXED-RATIO AND VARIABLE-RATIO EXCHANGE SCHEDULES[1]

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Rats' lever pressing produced tokens according to a 20-response fixed-ratio schedule. Sequences of token schedules were reinforced under a second-order schedule by presentation of periods when tokens could be exchanged for food pellets. When the exchange period schedule was a six-response fixed ratio, patterns of completing the component token schedules were bivalued, with relatively long and frequent pauses marking the initiation of each new sequence. Altering the exchange period schedule to a six-response variable ratio resulted in sharp reductions in the frequency and duration of these initial pauses, and increases in overall rates of lever pressing. These results are comparable to those ordinarily obtained under simple fixed-ratio and variable-ratio schedules.

Key words: second-order schedules, token reinforcement, variable-ratio schedules, fixed-ratio schedules, lever pressing, rats

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Under second-order chained and brief-stimulus schedules, behavior that satisfies the requirements of a component schedule is treated as a unitary response that is itself reinforced according to some schedule of reinforcement (*cf.* Kelleher, 1966). Under second-order token schedules, performance within component schedules of token delivery is reinforced according to the schedule for presenting the opportunity to exchange tokens for (usually) food (Malagodi, Webbe, and Waddell, 1975). Operationally, the delivery of tokens may be likened to brief presentations of exteroceptive stimuli, as in second-order brief-stimulus schedules, or, alternatively, the accumulation of tokens may be likened to successive changes in discriminative stimuli as in second-order chained schedules. Direct experimental comparisons of these three forms of second-order schedules have not been reported, but performance under token schedules most often resembles brief-stimulus rather than chained schedule performance (Malagodi *et al.,* 1975*b;* Waddell, Leander, Webbe, and Malagodi, 1972).

Because the completion of component schedules may be conditionable with respect to second-order schedule dependencies, second-order schedules have become important procedures for examining the generality of the effects of variables that contribute to the rates and patterns characteristic of schedule-controlled behavior in general (*e.g.,* Davison, 1969; Marr, 1971; see Gollub, 1977 for review). The use of second-order schedules within such an analytical context provides a means for extending the generality of schedule processes and the unitary effects of schedule variables from simple to complex behavioral situations (*cf.* Morse, 1966). For example, under simple fixed-ratio (FR) and fixed-interval (FI) schedules, the positive, direct relationship between post-reinforcer pause duration and schedule parameter value (Felton and Lyon, 1966; Schneider, 1969) is replicated under second-order FR and FI schedules (Malagodi; 1967*b, c;* Waddell *et al.,* 1972). Under simple fixed schedules at parameter values that generate marked post-reinforcer pauses, changing the schedule dependency from fixed to variable (at the same average parameter value) significantly reduces or even abolishes this pausing (Ferster and Skinner, 1957). Although the results of some studies suggest that a similar relationship between fixed *versus* variable second-order schedule dependencies and early pausing may obtain, the evidence is positive but indirect with brief-stimulus schedules (Byrd and Marr, 1969), equivocal with chained schedules (Find-

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ley, 1962), and mostly negative with token schedules (Kelleher, 1957; Malagodi, 1967*b, c*). Findley's (1962, p. 133) was the only systematic attempt at comparing performance under fixed and variable second-order schedules. He reported that extended early pausing was abolished and low overall rates were increased when FI 15-sec component schedules were reinforced under a variable-ratio (VR) rather than a FR schedule. However, since the comparison was between FR 5 and VR 3, the scheduled decrease in response requirement and, indirectly, the increase in reinforcement frequency under VR, might easily have been the major variable controlling the differential performance.

The object of the present study was to compare directly and unequivocally second-order token schedule performance under FR and VR schedules for presenting the exchange period. The rationale behind this approach was twofold. If the effect of varying the dependency between completion of unit schedules and reinforcement was similar to that obtained under simple schedules with discrete responses, then the general importance of that variable in controlling schedule performance is sustained. If the effect was different than under simple schedules, then experimental attention might be directed fruitfully to identifying factors in complex schedule arrangements that moderate the effects of a usually potent variable.

METHOD

Subjects

Three experimentally naive adult male Long-Evans hooded rats were maintained at 80% of their nine-month free-feeding weights. The rats were housed in separate cages, with water continuously available.

Apparatus

The experimental chamber contained a Gerbrands rat lever, a hopper into which dark clear glass marbles (tokens) were dispensed, a receptacle into which the rats deposited the marbles, and a food hopper into which 0.045-g Noyes standard formula food pellets were dispensed. A red light was located directly above the lever and a white light was located within the token receptacle (both lights were 6 W, 115 V ac). The chamber was housed within a ventilated, sound-attenuating exterior shell. An exhaust fan and white-noise generator provided masking noise. Automatic scheduling and recording equipment was located in an adjoining room. The experimental chamber and early training procedures are described in detail elsewhere (Malagodi, 1967*a*).

Procedure

The token reinforcement procedure used here was similar to those used previously with rats (Malagodi, 1967*a*) and chimpanzees (Kelleher, 1958). The notation system and descriptive terms such as *links* and *components* are common to the other forms of second-order schedules and have been standardized previously for this Journal (Malagodi *et al.*, 1975).

In the inital link, signalled by illumination of the red light above the lever, lever presses produced tokens according to a 20-response fixed-ratio schedule (FR 20: TOKEN), with each token delivery being accompanied by a 0.75-sec, 1000-Hz tone. In the terminal link, signalled by illumination of the white light inside the token receptacle and a continuous low-frequency clicker, each token deposited into the receptacle produced one food pellet (FR 1: FOOD). Under the baseline schedule arrangements, presentation of the terminal link depended on completion of six consecutive FR 20 token schedules in the initial link (FR 6: EXCHANGE). Lever presses in the terminal link had no scheduled consequences. Token deposits in the initial link did not produce food, but did reduce the possible number of food pellets that could be obtained in the succeeding terminal link. (Such "error deposits" occurred very infrequently and are not referred to again.)

After rates of lever pressing and patterns of completing component schedules had stabilized, the exchange schedule was changed from FR 6 to VR 6. Under VR 6: EXCHANGE, the terminal link was presented after an *average* of six tokens had been delivered. The actual number of tokens delivered in any given initial link varied between one and 14. The sequence of constituent ratios comprising the overall variable ratio was changed between sessions, and was derived from Fleshler and Hoffman's (1962) progression for equal-probability variable-interval schedules. Performance was allowed to stabilize under VR 6: EXCHANGE before FR 6: EXCHANGE was reexamined. (With Rat E-41, a second exposure

Table 1

The order of experimental conditions and the number of sessions under each condition.

Subject	*FR 6*	*VR 6*	*FR 6*	*VR 6*
E-40	26	39	48	
E-41	47	55	25	29
E-43	25	25	25	

at VR 6 was also conducted.) The number of sessions under each condition is presented in Table 1.

Stability criteria for manipulating the exchange schedule were as follows. The rats remained under each condition for a minimum of 25 sessions, and until the difference between the mean rates of lever pressing during the last five sessions and the preceding five sessions was less than 5% of the 10-session mean, with no systematic trends apparent.

Experimental sessions were conducted six days per week. Sessions terminated after delivery of 84 food pellets under FR 6: EXCHANGE, and after delivery of from 76 to 90 food pellets under VR 6: EXCHANGE.

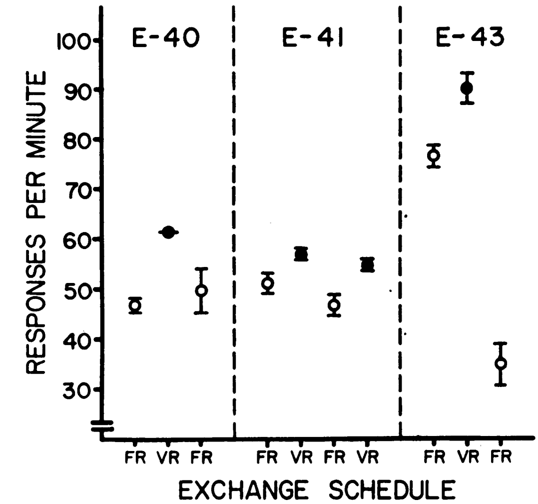

Fig. 1. Overall rates of lever pressing. Shown are means ± one standard error for the last five sessions at each condition.

RESULTS

The mean overall rates of lever pressing for the three rats during the last five sessions under each type of exchange schedule are presented in Figure 1. Higher rates with less daily variation occurred under VR: EXCHANGE than under FR: EXCHANGE. Because the effect was of small magnitude with Rat E-41, the second exposure under VR: EXCHANGE was conducted to ensure reliability. The second exposure under FR: EXCHANGE resulted in overall rates similar to those obtained previously with Rats E-40 and E-41. With Rat E-43, overall rates were much lower under the second exposure.

Qualitative and quantitative differences in patterns of lever pressing under the two types of exchange schedule are illustrated in Figures 2 and 3. Figure 2 shows representative cumu-

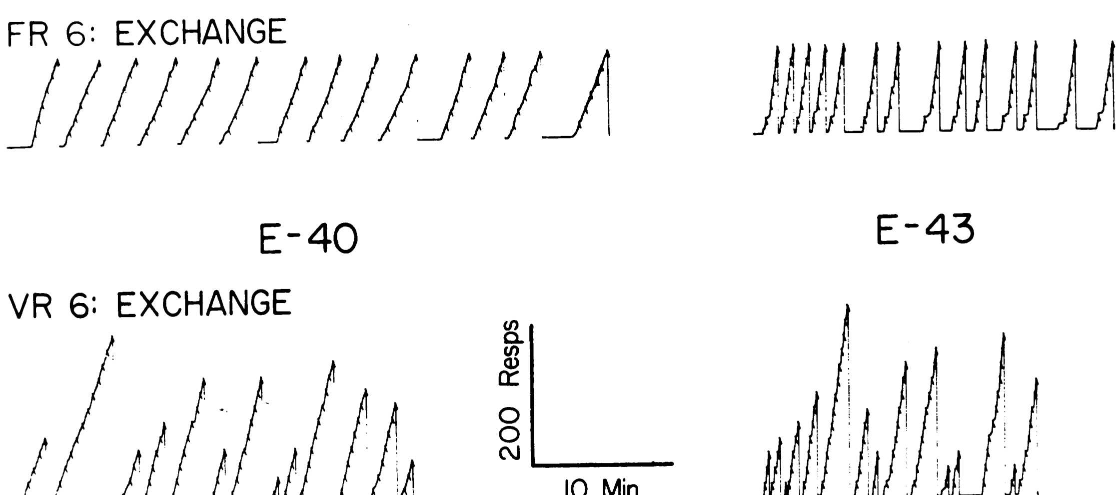

Fig. 2. Representative cumulative records of lever pressing for Rats E-40 and E-43. Diagonal hatchmarks indicate delivery of tokens under FR 20: TOKEN, and pen resets indicate completion of the FR 6 (top records) or VR 6 (bottom records) exchange schedule. Recorder did not operate while rats deposited tokens.

lative records for Rats E-40 and E-43 taken from the median of the last five sessions under FR: EXCHANGE (first exposure) and VR: EXCHANGE. Those from Rat E-41 were similar to those shown for Rat E-40. Figure 3 shows the mean pause time in seconds preceding the first lever press in each successive FR 20: TOKEN component for the last five sessions at each condition. For example, at the left of the figure, the first group of bars represents the pause duration from the start of each initial link until the first lever press occurred. Thereafter, each set of bars represents the pause duration from delivery of a token until the first lever press in the succeeding component. For clear comparisons between FR and VR exchange schedules, only the pause times for the first six FR 20: TOKEN components under VR are shown.

Taken together, Figures 2 and 3 show clearly that the increase in overall rate of lever pressing under VR: EXCHANGE was mainly a function of decreases in the frequency and duration of pauses preceding the first and second FR 20: TOKEN components. Pauses preceding the third through sixth components were already of short duration under FR: EXCHANGE, and were not changed systematically after the variable schedule was introduced. Under both FR and VR exchange schedules, successive precomponent pause durations decreased progressively until floor values were reached (usually after the fourth or fifth component). However, since the pause preceding the first component of the sequence was very long relative to later pauses, the overall pattern of completing the sequence of components under both FR and VR was best described as bivalued rather than positively accelerated (*cf.* Figure 2).

Within each component token schedule, lever pressing—once initiated—was maintained at high (E-43) or moderate (E-40 and E-41) constant rates, which also produced a characteristic bivalued response pattern. With Rats E-41 and E-43, local (running) rates were invariant across conditions. With Rat E-40, local rates increased progressively throughout the experiment. For example, in Figure 2, the slope of the cumulative curves for within-component responding is noticeably larger under VR than FR. On the second exposure under FR (not shown), local rates continued to increase, which indicated that these changes were

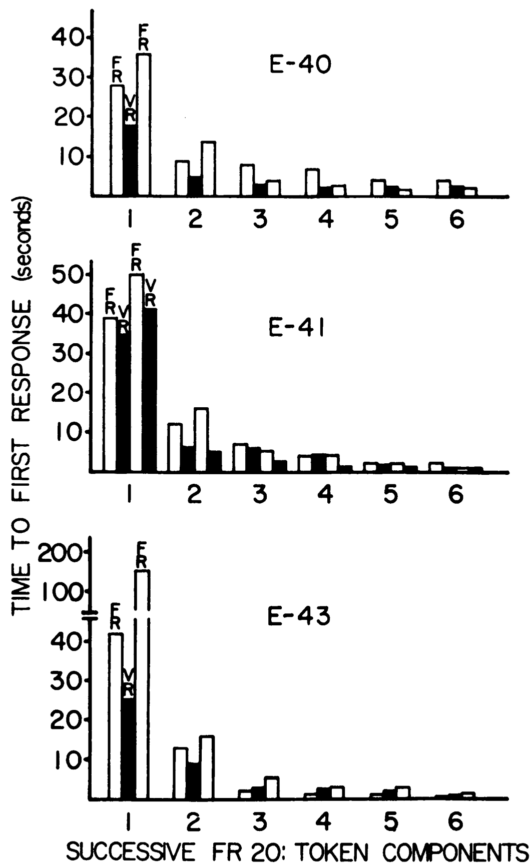

Fig. 3. Mean number of seconds spent pausing before the first lever press in each of the six FR 20: TOKEN components under FR 6: EXCHANGE, and in each of the first six FR 20: TOKEN components under VR 6: EXCHANGE. Criterion sessions are the same as in Figure 1.

probably not related to the exchange schedule manipulations.

With all three rats, the history of responding under VR EXCHANGE resulted in more pronounced early pausing on the second exposure under FR: EXCHANGE than under the initial exposure. As shown in Figure 3, this effect was most evident with Rat E-43. With respect to contrast and transitivity, it should be noted that this and the previously described changes in quantitative properties of performance caused by varying the exchange-schedule ratio were not abrupt. Rather, gradual transitions from one stable state to another were the rule of things.

Because quantitative descriptions of performance under VR schedules have been reported only rarely, it was of interest to compare the present results with respect to completion of component schedules to those obtained with discrete responses under simple schedules. In the only comparable experiment found, Kintsch (1965) reported on such distributions of lever-press interresponse times (IRTs) under VR 15 with two rats. His results, together with those from the present experiment, are shown in Figure 4. Most noticeably, a progressive decrease in IRT up to about the fifth response or second-order component characterizes both curves. The functions are also proportional, with that for the second-order components staying about one log unit above that for simple responses. However, because the comparison here is *post facto* and comprises a miscellany of averages, exact quantitative conclusions should be viewed with caution.

DISCUSSION

Under fixed-ratio exchange schedules, performance was characterized by bivalued patterns of completing individual and successive FR 20 component (token) schedules. Relatively long pauses preceded the first component, and succeeding pauses were much briefer overall, and of progressively shorter duration. Similar results with second-order FR 6 (FR 6) brief-stimulus schedules have been reported by Davison (1969). Under the variable-ratio exchange schedule, the bivalued patterns of completing individual and successive component schedules remained, but the frequency and duration of the pauses preceding the early components was decreased. Thus, the VR exchange schedule controlled higher overall rates of component completion than did the FR exchange schedule. These major results mirror the differences in performance between fixed- and variable-ratio reinforcement of simple, discrete responses (Ferster and Skinner, 1957; Kintsch, 1965). That this effect probably extends to other forms of second-order schedules is suggested strongly by results reported by Byrd and Marr (1969). Using both brief-stimulus and chaining procedures, they showed that sequences of FI 2-min component schedules were completed with minimal early pausing under a VR 12 schedule.

The failure to obtain differential effects with VR *versus* FR exchange schedules in earlier studies with second-order token schedules probably reflects the fact that these experiments were aimed at studying other processes, and the VR schedule was either employed briefly as a transition stage (Kelleher, 1957), or in assessing effects of schedule parameter on overall rates where schedule type differed between subjects, and baseline performance was not controlled for comparative purposes (Malagodi, 1967*b*, *c*).

The present results with respect to patterns of completing component schedules under overall VR schedules were consistent with those reported to obtain for simple VR reinforcement of discrete responses (Kintsch, 1965). Such a similarity across the dimension of response complexity probably obtains for FR schedules, although conclusions from previous experiments have differed in this regard. The progressive decrease to floor values in intercomponent latencies reported by Davison (1969) with FR 6 (FR 6: S) schedules and replicated here with FR 6: EXCHANGE (FR 20: TOKEN) schedules was unlike the bivalued distribution Davison (1969) and Blough (1963) found the simple FR 6 and FR 25

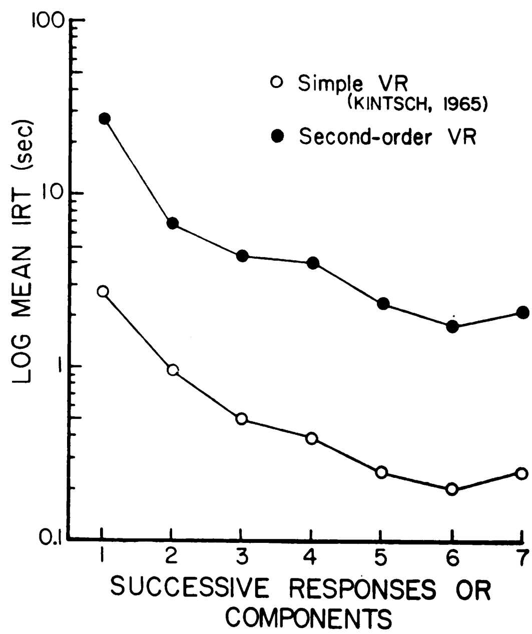

Fig. 4. Comparison of interresponse and intercomponent times under simple and second-order VR schedules. The lower curve represents the average of two animals across 14 sessions of VR 15 (Kintsch, 1965). The upper curve represents the average for E-40, E-41, and E-43 under VR 6: EXCHANGE (FR 20: TOKEN), and was constructed from the same data pool from which Figure 3 was drawn.

schedules. However, these patterns with second-order schedules are quite consistent with those shown for FR 30 by Gott and Weiss (1972) in a much more precise quantitative analysis of FR response patterns. Their three-state analysis of FR response patterns—pause, "junction" period, constant rate (minimal IRT)—appears to be representative of most other descriptions of FR performance (see Zeiler, 1977 for review).

In conclusion, the use of complex schedule arrangements to investigate properties of schedule-controlled behavior reflects a "macro" approach to behavior analysis. Just as the interactions that arise from the scheduling of concurrent operants may reveal basic properties of behavior that are masked in unelaborated situations, so also may the effects of schedule variables be manifested differently when reinforcers depend on completion of functional response units rather than single responses. Encouraging for the analysis (and for the analysts), is the fact that most experiments with second-order schedules utilizing the approach represented here, have reported generality of schedule processes and unitary effects of schedule variables, rather than uncovering disparities (Kelleher, 1966; Shull, Guilkey, and Witty, 1972; Waddell *et al.*, 1972).

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